Renewable and Sustainable Energy Reviews 22 (2013) 655–666

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Motivations and barriers associated with adopting microgeneration energy technologies in the UK

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ARTICLE INFO

Article history:
Received 16 November 2012
Received in revised form
2 February 2013
Accepted 10 February 2013
Available online 21 March 2013

Keywords:
Microgeneration energy
Renewables
Consumer attitudes
Motivations and barriers

ABSTRACT

Despite significant financial support from the UK government to stimulate adoption of microgeneration energy technologies, consumer uptake remains low. This paper analyses current understanding of motivations and barriers that affect microgeneration adoption with the aim of identifying opportunities for improving the uptake. The findings indicate that, although feed-in tariffs have increased the uptake, policies do not sufficiently address the most significant barrier – capital costs. 'Environmental benefit' appears to be a significant motivation to install, but there is doubt whether consumers are willing to pay extra for that. The issue is complicated by the fact that motivations and barriers differ between segments of the population, particularly with age. Younger age groups are more willing to consider installing but less frequently reach the point of installation, suggesting that other barriers such as costs prevent them from installing. Further investigation into these factors is required to understand how uptake may be increased.

Contents

1. Introduction

In the UK, microgeneration is defined as the generation of electricity of up to 50 kW and/or heat of up to 45 kW from a low-carbon source and includes the following technologies [1]:

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http://dx.doi.org/10.1016/j.rser.2013.02.012

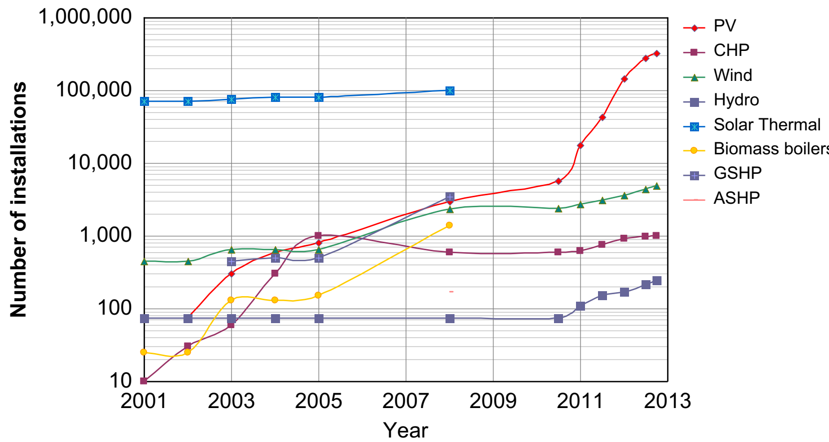

Fig. 1. Increase in the number of installations from 2001 to 2012. [Estimates based on the following sources: 2001–2005: Element Energy [12]; 2008: Element Energy [8]; 2010–2012: DECC [9]. For calculations, see Appendix A].

- electricity: solar photovoltaics (PV), micro-wind, micro-hydro, micro-CHP and fuel cells;
- heat: solar thermal, air source heat pumps (ASHP), ground source heat pumps (GSHP), water source heat pumps (WSHP), biomass stoves and boilers.

This scale of generation is suitable for installation in domestic and non-domestic buildings, including offices, schools, shops, hotels and factories.

The UK government aims to increase the uptake of microgeneration technologies as part of its strategy to improve energy security and reduce greenhouse gas (GHG) emissions [2]. Given that the residential sector accounts for 30% of UK energy consumption [3] and other, non-residential, buildings account for 18% [4], reductions in GHG emissions within these sectors could contribute significantly to meeting the UK climate change targets.

To stimulate the adoption, the Feed-in Tariff (FIT) scheme was introduced in April 2010, significantly reducing capital payback times [5,6]. The FIT scheme offers a payment for each unit of electricity generated to approved, grid-connected, electricity microgenerators of less than 5 MW capacity. There are additional payments for electricity exported back to the grid. Technologies eligible for payments are solar PV, wind, hydro, anaerobic digestion and CHP. The payment, which is guaranteed over 20–25 years (apart from CHP which is guaranteed for 10 years), is made by the energy supplier companies and their costs are recouped by increasing consumer electricity prices. Payments are different for each technology and for different capacities of installation and are based on providing a 5% return on investment. In addition, the government has developed a Microgeneration Strategy to tackle non-financial barriers to greater deployment, such as uncertainties in performance and reliability, by ensuring supplier accreditation through the Microgeneration Certification Scheme[1] [7].

Government support for microgeneration has helped to increase uptake, especially of solar PV, which has grown from around 3000 installations in 2008 [8] to 320,000[2] in 2012 [9]; see Fig. 1. However, the uptake of other technologies has been much slower and the total contribution of microgeneration is still low, meeting less than 0.2% of the final energy demand in the UK domestic sector (see Appendix A for the estimation). This suggests that there are significant barriers to adoption which must be reduced or removed if microgeneration is to contribute to UK climate change targets and energy security.

In an attempt to assist in identifying the barriers as well as motivations for adoption, this paper reviews and discusses the current understanding of different factors affecting consumers when considering installing microgeneration technologies. The paper also seeks to identify any gaps in knowledge about motivations and barriers, and makes recommendations for further research.

In total, 18 relevant studies have been found in the literature; they are summarised in Table 1. As can be seen, the majority of the studies are based in the UK and all except one (Japan) are in Europe. As also indicated in Table 1, a number of different methods of survey and analysis have been employed to elicit attitudes towards microgeneration: open ended interviews with qualitative analysis; closed format questions or rating scales with descriptive statistical analysis; closed format questions with regression analysis; and environmental valuation economic methods.

The next section reviews motivations and barriers associated with microgeneration adoption identified within the literature. This is followed by a review of how perceptions of microgeneration differ between subgroups of the UK population in Section 3. Conclusions and recommendations for further research are given in Section 4.

2. Motivations and barriers

There are many consumer motivations and barriers associated with microgeneration adoption that have been cited in the literature. They can be categorised as: finance, the environment, security of supply, uncertainty and trust; inconvenience and impact on residence. They are summarised in Table 2 and discussed below broadly in the order of their relative importance in the adoption decision as identified from the literature, although with the exception of finance and environment, there is little agreement on the importance of different motivations and barriers across the literature. Note that some of the motivations and barriers in Table 2 could be assigned to more than one of the categories (e.g. the requirement for planning permission could also be a financial barrier), but have been allocated to the

[1] The Microgeneration Certification Scheme is a quality assurance mechanism to set a minimum standard for microgeneration products and installations.

[2] Figure of 320,200 is derived by adding the estimated installations in 2008 (2993) from Element Energy [8] and the number of installations registered with Ofgem as part of the FIT scheme [9] by September 2012 (317,172). As the FIT register only accounts for those within the scheme, this estimation ignores any installations not in the FIT scheme that were installed after 2008. Consequently, this may be an underestimate. See also Appendix A for further details.

Table 1
Summary of surveys carried out related to attitudes to microgeneration.

Author	Year	Location	Sample	Aims	Type of survey	Technologies considered	Analysis
1. Brook Lyndhurst et al. [26]	2003	UK (London)	502 London residents	Identifying the public's attitudes towards climate change, renewables and microgeneration	Face-to-face interviews Both open and closed ended questions	Solar, wind, CHP[a]	No information
2. Fischer [27]	2004	Germany	142 fuel cell CHP owners	Identifying the socio-demographic profile of fuel cell CHP users, as well as their attitudes to energy and environment and perceptions of CHP.	Postal survey with closed ended questions and agreement rating scales	Fuel cell micro CHP[a]	Using mean average responses and comparing to the general German public
3. ORC International [16]	2004	UK (London)	601 London residents	Identifying the public's attitudes towards climate change, renewables and microgeneration	Telephone interviews Both open and closed ended questions	Solar PV, solar thermal, wind	Descriptive statistics and cross tabulations
4. Curry et al. [28]	2006	UK	1056 UK residents	Identifying the public's attitudes towards climate change and renewable energy	Online questionnaire closed format questions	Solar, wind, biomass	No information
5. Faiers and Neame [29]	2006	UK	43 UK 'early adopters' and 350 UK 'early majority'	Investigating the difference in attitudes towards solar thermal and PV systems between early adopters and the early majority	Kelly's repertory grid survey Closed ended questions 0–13 agreement scale	Solar thermal, solar PV	Segmented sample by innovation theory groups
6. Jager [30]	2006	Holland	197 Dutch solar PV adopters	Identifying behaviour-related motivations to installing solar PV	Closed ended questions Likert agreement scale	Solar PV	Univariate analysis of importance of motivations against environmental awareness. Segmentation of high awareness and low awareness
7. Keirstead [31]	2007	UK	91 UK solar PV adopters	To understand factors affecting the adoption decision and to identify whether energy use behaviour changes after microgeneration adoption	Semi-structured face-to-face interviews and closed-format posted questionnaires	Solar PV	Descriptive statistics
8. Mahapatra and Gustavsson [32]	2008	Sweden	630 and 711 (two surveys) Swedish detached homeowners	Identifying factors affecting homeowners' decisions to adopt microgeneration systems.	Postal survey with closed ended questions and agreement rating scales	GSHP[b], biomass boilers	Mean average responses of agreement scales
9. Goto and Toshio [33]	2009	Japan	3431 Japanese residents	Identifying the most important factors that affect preferences for solar PV and fuel cell technologies	Closed ended questions Likert agreement scale	Solar PV, fuel cell	Multivariate regression preferences for different microgeneration systems against capital costs, operating costs, environmental benefit etc.
10. Caird and Roy [15]	2010	UK	545 adopters, 314 considerers, 65 rejecters	Determining the motivations and barriers associated with installing heat producing microgeneration technologies in households, UK	Online questionnaire multiple choice and open ended questions	Solar thermal, GSHP[b], biomass boilers	Descriptive statistics and cross tabulations
11. Claudy et al. [11]	2010	Republic of Ireland	1010 Irish residents	Defining the importance of socio-demographic factors that affect the awareness of microgeneration.	Telephone interview with closed ended questions	Solar PV, solar thermal, wind, CHP[a], heat pumps, biomass boilers	Regression of awareness on demographic information
12. Scarpa and Willis [13]	2010	UK	1279 UK homeowners	Estimating the WTP[c] for different microgeneration technologies and the influence of perceptions on WTP[c]	Choice experiment	Solar PV, solar thermal, wind	Various logit models to regress the decision to adopt microgeneration against capital costs, maintenance bill, energy costs, inconvenience etc
13. Sopha et al. [34]	2010	Norway	649 Norwegian homeowners	Identifying factors that affect the decision to switch to wood pellet boilers and heat pumps from electric heating	Postal survey, closed ended questions with multiple choice and Likert agreement scale ratings	ASHP[d], biomass boilers	Regression of choice of heating system against socio-demographics and various product- and choice-related factors
14. Warren [35]	2010	UK (Camden, London)	17 small-sized companies	Determining the motivations and barriers associated with installing microgeneration technologies in commercial buildings in Camden, UK	Semi-structured face-to-face open ended interviews	Solar PV, solar thermal, wind, CHP[a], biomass boilers, ASHP[d], GSHP[b]	Qualitative
15. Palm and Tengvard [36]	2011	Sweden	20 Swedish homeowners: 9 adopters, 8 considerers, 3 rejecters	Determining the motivations and barriers associated with installing solar PV and wind systems in Swedish households	Half face-to-face and half telephone interviews Open ended questions	Solar PV, wind	Qualitative
16. Claudy et al. [37]	2011	Republic of Ireland	1012 Republic of Ireland homeowners	Estimating the WTP[c] for different microgeneration technologies and the importance of different factors in the adopting decision	Contingent valuation method	Solar PV, solar thermal, wind, biomass boilers	Bivariate probit model to regress the decision to adopt against various 'innovation theory' factors
17. Consumer Focus [38]	2011	UK	1223 UK residents (and 2655 UK residents for the microgeneration experience survey)	Identifying attitudes towards, microgeneration in terms of adoption and experience, and developing a profile of those at different stages of consideration	Focus group discussion (12), face-to-face interviews (40) and online questionnaires (1223)	Solar PV, solar thermal, wind, CHP[a], hydro, biomass boilers, heat pumps	Descriptive statistics
18. Leenheer [39]	2011	Holland	2047 Dutch residents	Defining the factors that affect the motivation to install microgeneration	Closed ended questions Likert agreement scale	Any electricity microgeneration	Descriptive statistics and a multivariate regression of the intention to adopt against environmental concern and independence from centralised energy generation

[a] CHP: Combined heat and power.
[b] GSHP: Ground-source heat pumps.
[c] WTP: Willingness to pay.
[d] ASHP: Air-source heat pumps.

Table 2
Summary of motivations and barriers associated with adopting microgeneration as found in literature.

	Motivation	Barrier
Financial	– Save or earn money from lower fuel bills and government incentives – Increase the value of my home	– Costs too much to buy/install – Cannot earn enough/save enough money – Lose money if I moved home – High maintenance costs
Environmental	– Help improve the environment	– Environmental benefits too small
Security of supply	– Protect against future higher energy costs – Make the household more self sufficient/less dependent on utility companies – Protect the household against power cuts	– Would not make me much more self sufficient/ independent
Uncertainty and trust	– Use an innovative/high-tech system	– Home/location not suitable – System performance or reliability not good enough – Energy not available when I need it – Hard to find trustworthy information/advice – Hard to find any information/advice – Hard to find trustworthy builders to install
Inconvenience	None identified	– Hassle of installation – Disruption or hassle of operation – Potential requirement for planning permission
Impact on residence	– Improve the feeling or atmosphere within my home – Show my environmental commitment to others	– Take up too much space – The installation might damage my home – Would not look good – Neighbour disapproval/annoyance

category to which they are most-closely related. These are discussed below.

2.1. Finance

It is well recognised that costs are the largest barrier to microgeneration adoption (e.g. [10–14]). Capital costs are too high for the majority of potential adopters and the payback times are too long to warrant the large investment [13]. For example, Caird and Roy [15] found in an online survey of microgeneration 'adopters' (545), 'considerers'[3] (314) and 'rejecters' (65) that the most frequently cited barriers to installing microgeneration systems were all related to costs: capital costs (86% of the respondents), long payback time (68%) and lack of grants (60%). A survey of 601 London home-owners by ORC International also found capital costs to be the most important barrier while assistance with costs was the most cited motivation (by over 75% of respondents) [16].

Since 2004, there has been a VAT reduction to 5% on micro-generation products to reduce capital costs [41]. However, for microgeneration technologies besides solar PV and solar thermal, there is still a significant gap between consumers' willingness to pay (WTP) and capital costs [13,37]. This is shown in Table 3, which indicates that the only technology for which the mean WTP was equivalent to the capital costs was solar thermal. This is not surprising as the total number of solar thermal panels at the time these surveys were carried out (2007 and 2009) far outweighed other technologies: 90,000 units compared to around 3000 solar PV installations and less than 5000 of other technology types [17] (Fig. 1). This has resulted in low demand for microgeneration technologies, hindering market development and preventing cost reductions associated with a maturing market [18].

However, UK demand for solar PV has significantly increased since 2007 and 2009 when these two studies were carried out and is now the dominant technology in terms of number of installations (see Fig. 1 and Appendix A). The main cause of this shift is the introduction of the FIT scheme in 2010 which has led to reduced consumer prices owing to a maturing solar PV market and consequently increased consumers' WTP. For example, as indicated in Fig. 2, UK installed levelised costs before the FIT were around £7000/kWp and by 2012 they were almost four times lower, down to about £2000/kWp [19–24]. These cost reductions have, in turn, led the UK government to reduce the FIT rates by half for solar PV (from 45 to 21 p/kWh) from 2012, whilst for the other technologies the rates have remained unchanged [25].

Table 3
Comparison of capital costs and consumer willingness to pay (WTP).

Type	Levelised cost (£/kW)[a]	Levelised mean WTP[b] (£/kW)	Acceptable payback time (yrs)	Year	Source
Solar PV (2 kW)	5319	1416	N/A	2007	[13]
Solar PV (3 kW)	6383	2069	9	2009	[37]
Wind (1 kW)	4998	1288	N/A	2007	[13]
Wind (5 kW)	5830	1685	11	2009	[37]
Solar thermal[c]	1575	1920	12	2009	[37]
Solar thermal (2 kW_{th})	1952	1452	N/A	2007	[13]
Biomass boiler (wood pellets)[c]	1000	489	7	2009	[37]

[a] Costs as cited by the relevant study.
[b] WTP: Willingness to pay.
[c] The size and capacity of the system was not stated within the study. UK average peak capacities of 2 kW for solar thermal and 11 kW for biomass boiler have been used as in [13] and [40].

[3] Considerers were defined within the study as those considering the purchase of a microgeneration system and rejecters as those that considered but decided against purchasing.

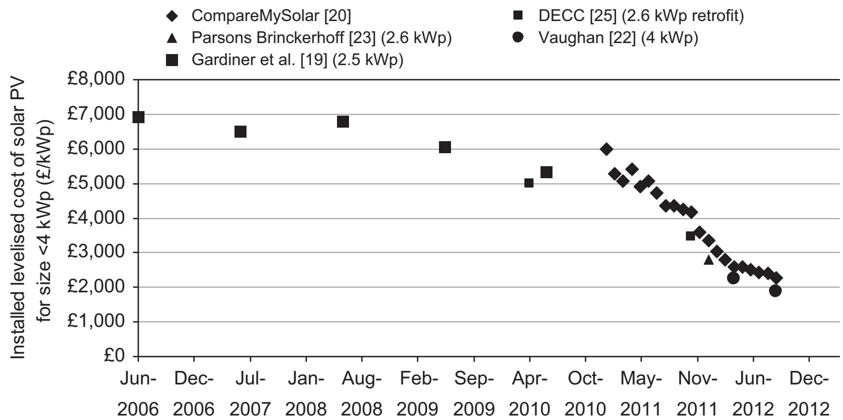

Fig. 2. Decrease in capital costs of solar PV installations in the UK from 2006 to 2012 (£/kWp). [Actual prices shown, not adjusted for inflation.]

There is a clear financial trade-off between capital costs and the motivation to save or earn money from lower fuel bills and FIT incentives, often represented as payback time. Prior to the introduction of FIT, payback times were too long for most consumers: 15–18 years for wind turbines, 8–53 years for solar thermal [41,42] and 35–58 years for solar PV [41,43]. In comparison, [37] estimated mean payback times that were acceptable to potential adopters as nine years for solar PV, 11 years for wind and 12 years for solar thermal (see Table 3). Scarpa and Willis [13] estimated an aggregated acceptable payback time as 3–5 years across the three microgeneration products considered. This gap between acceptable and expected payback times has been significantly reduced for some technologies due to the introduction of FIT as well as increasing electricity and gas prices and reduced capital costs, which are discussed in Section 4. For example, one study estimated a payback time of 11 years for solar PV [6] which is much closer to the estimated acceptable payback time (see Table 3). FIT payments have clearly increased demand for microgeneration, evident from the increase in uptake as well as a survey cited within the UK Microgeneration Strategy, stating that 40% of those who were considering adoption said they would not consider it without the FIT incentives [7].

Another frequently cited cost-related barrier is concern about the resale value of the home. The ORC International study found that many[4] respondents expressed concern that potential future house buyers would be put off by a microgeneration installation which could lead to a decrease in house price. Faiers and Neame [29] also investigated whether potential adopters thought microgeneration would be a positive influence on house sales, but suggested that this was not an important issue in the decision to adopt.

There is limited evidence as to the effect of solar PV installations on house prices. Two studies from the USA find that house prices tend to increase almost proportionally to the installation costs [44,45]. However, only one UK study was found [46], conducted prior to the introduction of FIT in 2010, which reported a negligible positive increase in house value associated with solar PV installation. There are also a number of articles on the subject (e.g. [47–50]), which provide conflicting conclusions. Thus, the impact on property value is very much unclear, adding to confusion and most likely posing an additional barrier to potential adopters, especially those who consider themselves more likely to want to resell (or remortgage) their property in the short to medium term.

[4] The number of respondents was not specified within the report.

As with capital costs and operational savings, potential adopters may also consider a trade-off between capital costs and environmental benefits in their adoption decision. This is suggested by studies conducted by Brook Lyndhurst et al. [26] and Curry et al. [28]. In the former study, respondents were asked to 'leave aside cost' whilst considering installing solar thermal or solar PV. On this basis, 23% of households were 'very likely' to consider it, with another 34% 'fairly likely'. When presented with the cost implications, support fell to 4% ('very likely') and 70% said they were 'certain not to' install. Similarly, Curry et al. [28] found that there was less support for renewable energy to help mitigate against climate change when supporters were made aware of associated costs, which prompted a small shift in support of nuclear energy. These two surveys demonstrate how capital costs can counter other motivations to install microgeneration such as operational savings, or the perceived benefit to the environment. The latter is discussed next.

2.2. Environment

Along with economic costs, environmental benefit appears to be a significant factor in the decision to install microgeneration [11,39]. Microgeneration is generally perceived to be environmentally friendly, perhaps by its very definition as a 'low-carbon source' of energy. Some of the potential adopters are driven by the desire to reduce GHG emissions and most believe microgeneration will help achieve it. For example, 'reducing carbon dioxide emissions' was ranked as the most important motive for purchasing a system within the Caird and Roy study [15] and was considered an important factor in the adoption decision in a study of Dutch households by Leenheer et al. [39].

Although for many there is a desire to be more environmentally friendly [28], a number of studies suggest that this desire does not translate into a willingness to pay extra for it [11,51,52]. Many adopters might be environmentally aware, but will make a purchase decision based on cost and factors other than environmental benefit [52,53]. For instance, Wimberly [52] surveyed the American public on their perceptions of energy efficiency and renewable energy and found that the sample placed much more importance on saving money than on reducing their environmental impact. Another study [54] highlights the sample's unwillingness to reduce their environmental impact: "It is almost as if consumers are holding their noses to take medicine they perceive to taste awful but is necessary to bring the fever down" [54].

Microgeneration technologies may be perceived by the public as low-carbon, but there are other associated environmental

impacts that may be viewed differently. For example, a study of 49 Norwegian residents found that some respondents thought air source heat pumps would produce more indoor air pollution owing to assumed dust recirculation from a heat pump [34]. Warren [35] also noted that participants raised concerns over the impact of biomass boilers on air quality. This study of 17 small businesses in Camden, London, also found environmental benefit and promoting a 'green' image for the company to be important motivations for installing microgeneration technologies [35].

Promoting a 'green' image by installing a publicly visible system such as solar panels or a wind turbine is also a motive for some residential consumers [15,36]. Palm and Tengvard [36] surveyed Swedish households considering the purchase of a 'DIY install'[5] microgeneration system. The study investigated motivations and barriers associated with purchasing these products for respondents at different stages of their decision using 20 semi-structured inductive interviews. As well as being able to visibly demonstrate environmental commitment, another significant motivation was 'to set an example for others' [36]. Those who are motivated to visibly demonstrate their environmental commitment may want to identify themselves with a low-carbon, 'green' image, to use microgeneration to send an environmentally friendly message to others [30,55]. Fischer and Sauter [56] suggest that installing solar PV, in particular, is a clear socio-political statement, one that appeals to those with "green political orientation and postmaterialist values".

As well as reducing GHG emissions and creating a 'green' image, some potential adopters are also motivated by the desire to use a low-carbon, innovative technology. Caird and Roy [15] found when existing adopters and considerers were asked what drove them to consider microgeneration that a fifth of the sample (sample size $N=859$) stated that they wanted to use innovative, pioneering low-carbon technology and a fifth either worked in a field relating to energy, environment or technology, or it was a personal interest of theirs. Fischer [27] and Leenheer et al. [39] also suggest that those who have an affinity for technology are more likely to want to generate their own energy using microgeneration.

2.3. Security of supply

The issue of independence or security of supply in the adoption decision encapsulates the motivation for increased energy self-sufficiency, being able to reduce reliance on the gas or electricity grid and being less susceptible to future energy price increases [11,30,33,36,39,57]. Praetorius [58] suggests that consumers are motivated to guard against fuel bill increases owing to an increase of 45% in UK electricity and 71% in gas bills from 2003 to 2007, which has lead to increased public interest in microgeneration. Leenheer et al. [39] identified the desire within the sample to generate own power as important in the decision to adopt microgeneration. However, there was significant focus within this survey of Dutch households on the risk of power outages, which has not been considered in any UK based research, so it is not clear if this would be as relevant to the UK public.

Jager [30] also found that independence from centralised energy generation was an important motivation to adopt solar PV systems. A survey of 197 Dutch households with solar PV systems found that increased independence was a greater motivation for those with higher environmental awareness. In other words, the study identified a segment of the population who identify themselves as environmentally aware and desiring self-sufficiency. Palm and Tengvard [36] also suggest that this motivation is linked to a desired environmentally-benign, self-sufficient identity, which is perhaps similar to the environmentally-friendly image mentioned in Section 2.2.

2.4. Uncertainty and trust

A frequently cited barrier to installing microgeneration systems relates to a lack of confidence that the system will perform as desired. Whilst some studies suggest potential adopters are motivated to install by confidence in performance and reliability (e.g. [15]), many studies cite barriers such as performance uncertainties [15,16,26,59], uncertain payback on investment [13,15], uncertainty over the reliability, or even lack, of general and technical information, and uncertainty over the potential benefits of microgeneration [16,60].

Performance and reliability uncertainties were significant barriers to adoption to 58% of rejecters within the Caird and Roy study [15]. This uncertainty also features within the Microgeneration Strategy [7], which suggests that those who have not yet considered adoption lack confidence in the technologies as well as the suitability of their homes and suggest that this is an information-related barrier. This barrier develops as most consumers begin an initial investigation into microgeneration on the internet, where it may be difficult to find information they trust [7].

The lack of trust in the performance and reliability of microgeneration systems has been identified in many studies [16,61]. The ORC International study also found that there was a lack of awareness of information and advice centres: only 35% knew that there were energy advice centres and many respondents called for more product-specific information [16]. Owing to the relatively low number of microgeneration installations in the UK with the exception of solar PV, perhaps there is a lack of visible examples of microgeneration systems in the public eye, contributing to the lack of awareness, confidence and high degree of scepticism in the technologies [60]. This is corroborated by Caird and Roy [15] who found that potential adopters wanted to see examples of microgeneration systems on local residences and public buildings. Similarly, Scarpa and Willis [13] found that positive perceptions or advice from friends or trusted experts increased willingness to purchase microgeneration (shown by an increase in WTP of £263 with advice from a heating engineer).

However, the difficulty in finding a trusted expert also represents a barrier to adoption [7]. The government Microgeneration Strategy suggests that potential adopters fear that advice from installers will not be impartial, regardless of whether they are approved by the Microgeneration Certification Scheme or not [7].

2.5. Inconvenience

As well as finding an appropriate installer, the inconvenience of major modifications to heating or electrical systems, or to the roof or garden during installation, is also a significant barrier to adoption [13–16]. For example, installing a residential GSHP may require the garden to be dug up to install a ground heating loop (further discussed in Section 2.6). Warren's [35] research with potential adopters for non-domestic buildings found that there was most interest in CHP systems due to the similarity with existing boiler systems and the fact that it could be a replacement rather than an additional system. However, initial awareness of the technology was low, supporting the suggestion that there is an information-related barrier as discussed in Section 2.4.

Additionally, the perceived difference in the day-to-day use of a microgeneration system compared to an existing system is a factor in the adoption decision. Many potential adopters are put off by

[5] 'DIY install' microgeneration products are designed to be installed, set up and connected by anyone, without the need for expert installers (solar PV and wind were considered in the study).

inconveniences such as a greater space requirement, refuelling (e.g. wood pellet boilers) and modifications to the garden [13].

A perceived increase in maintenance and the complexity associated with a system change is also a barrier to adoption. Element Energy [17] found that respondents, of which the majority were already considering installing microgeneration, were willing to pay an average £6 in upfront cost to negate every £1 of annual maintenance cost for heating systems. With solar PV, solar thermal and wind, this WTP rose to around £10, perhaps due to perceived complexity or 'the unknown' nature of these technologies. The NHBC Foundation [3] stresses the need for the industry to minimise additional service and maintenance responsibilities for the adopter and reduce the need for system intervention, such as refuelling, as much as possible. There are a number of warranties and insurances offered by suppliers and the REAL Assurance Scheme Code, an accreditation scheme for suppliers, stipulates a requirement for basic information on the warranties that are offered [7]. However, at present there is no drive from the government to regulate service and maintenance contracts with suppliers that may ease fears amongst consumers. The Microgeneration Certification Scheme regulates the quality of the product and installation, but there is no regulation of post-installation servicing or product care. The government have recognised the need to tackle this barrier of increased maintenance but have tasked the industry to provide assurances to consumers instead of providing regulation or direction [7].

Additionally, a barrier to adopting microgeneration may simply be that households are generally content with their existing system and thus see the replacement of their system as a low priority since there is not enough perceived relative advantage [17]. Claudy et al. [11] define microgeneration as a 'resistant innovation', since increased uptake requires potential adopters to alter significantly their daily routines and traditions, which represents an inconvenience. Alternatively, this barrier could be negligible for those who are already planning home modifications [15,31,38]. Combining a microgeneration installation with other house modifications also tends to reduce costs; for example, fitting solar panels at the same time as roof modifications means the same scaffolding could be used, reducing a significant cost.

2.6. Impact on residence

Some microgeneration technologies use a significant amount of space within the home which is a barrier for some potential adopters [13,15,26]. The value of space is often significant, but will vary across different population groups as well as locations. Those living in a city, for example, where space is at a premium, may not be able to even consider a technology such as a GSHP, where horizontally-laid heating loops in particular require a lot of space. This was also confirmed by a study with owners and managers of offices within high-rise buildings [35], where floor space is valued highly. Respondents were generally of the opinion that GSHPs were not practicable, with not enough space for horizontal heating loops and vertical loops were unlikely to be allowed due to underground utility lines and the underground tube system.

New-build housing which allows for, or already has fitted, microgeneration would eliminate the space issue. For this reason, legislation for new developments will begin phasing into building regulations the requirement for efficient energy use and connection to either household microgeneration systems or to small, low-carbon distribution networks [62]. The zero-carbon homes policy requires all new homes to be built with a high-energy efficiency rating and access to a low-carbon fuel source by 2016 [63]. However, the retrofitting of existing homes, of which there are over 25 million, will remain an issue and may reduce significantly the microgeneration options available for those households.

Another frequently cited barrier to installation is concern about disapproval of neighbours regarding the aesthetics of microgeneration installations [16]. Palm and Tengvard [36] also found that fear of neighbour disapproval is a barrier to adoption. This may be particularly important for wind turbine installations due to the social stigma associated with their aesthetics [64]. This barrier seems to be in contrast to the 'demonstrating environmental commitment' motive (Section 2.2).

In summary, as discussed in this section, there are many factors that affect the decision to install microgeneration. Additionally, there are some significant differences in the attitudes across the UK population, with many of these factors being barriers for some people, but motivations for others. The following section reviews these differences in perceptions among different societal groups.

3. Differing perceptions within subgroups of the UK population

A number of studies have attempted to find correlations between differing perceptions of microgeneration and the characteristics of the person, the household in which they reside or their experience of microgeneration (whether they are adopters, considerers or rejecters). This section gives an overview of current understanding of these differing perceptions and suggests reasons as to why demand is higher for some groups than others and what policies might improve microgeneration uptake among those who have not installed. A summary of the demographic factors and the expected correlation with the likelihood of adoption is given in Table 4.

3.1. Age

It has been found in a number of studies that attitudes towards microgeneration differ across age groups [32,38,39,65,66]. The number of microgeneration installations is lower amongst those

Table 4
Correlations between several demographic factors and likelihood of adoption.

Demographic	Correlation with adoption	Source
Age	Inverted 'u' shaped correlation OR increase of adoption with age until 65, with a sharp decrease afterwards OR decrease of adoption with age	[11,32,66]
Household size	Increases with size	[15,31]
Homeowners/tenants	Almost all adoption is by homeowners	[31,56]
Family size	No correlation found	[16]
Social class	Upper-middle class most likely to adopt	[16,68,65]
Income	Adoption increases with income OR middle income most likely to adopt	[31,34]
Education	Adoption increases with education	[31,56]

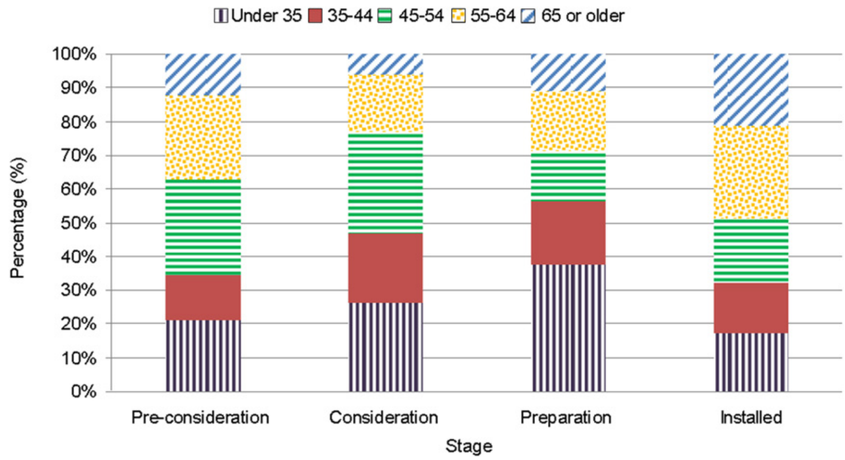

Fig. 3. The percentage of each age category associated with different consideration stages [38].

who are below 45 [16,65] and those above 65 years old [39,65,66]. This correlation has been found in several studies, where 45–64 year olds are either the most commonly aware of microgeneration [11], have a more positive attitude towards it [65], or are the age group most likely to install [32,56]. Older age groups are less inclined to adopt new technologies such as microgeneration [34,66], exhibiting a greater resistance if they have been using their existing system for many years [32]. This is perhaps due to the security of knowing that the existing system works, combined with the uncertainty of a new, untried, system (see Section 2.5). Willis et al. [66] find there is even 'disutility' for adopting microgeneration with over 65 year olds, suggesting that this age group would actually pay not to install microgeneration. They also find that there is a discontinuous relationship where adoption increases with age until retirement after which there is a significant drop in uptake.

The cause of the reduced number of installations amongst over 65 year olds could be due to their different financial position. The trade-off between high capital costs and fuel savings/FIT incentives, described in Section 2.1, is perhaps particularly relevant for retired households. In terms of capital costs, pensioners are likely to have lower incomes than before retirement, which may reduce their willingness to invest in costly microgeneration. Conversely, it is suggested by Faiers and Neame [29] that the decrease in income owing to retirement may drive a desire for future fuel savings, to economise on expenditure, which makes an investment that reduces fuel bills more attractive. Willis et al. [66], however, find that pensioners are actually less sensitive to change in fuel bills. This could be because pensioners are concerned about depleting their capital savings, whilst being less affected by rising energy costs [66] owing to Winter Fuel Payments for pensioners in the UK [67].

The visible increase in microgeneration installations up to retirement age indicates that there are fewer, or perhaps reduced, barriers to adoption for older working households. This may be due to higher incomes amongst older working households (see Section 3.3) or simply that there are more home owners aged 45–65 than younger age groups (see Section 3.2). Additionally, there may be more of a financial motive to install in this age group who have the capital to invest, rather than younger age groups who are more environmentally aware [16] but may not have the capital.

Other studies suggest different correlations between age and microgeneration adoption. Surveys of Swedish home owners in 2004 and 2007 revealed the number planning to adopt microgeneration, particularly pellet boilers and heat pumps, decreased with age, with the exception of those aged 36–45, who were most likely to install [32]. Keirstead's [31] study of 91 solar PV owners revealed the adopters to be generally older, with 92% being over 45. However, there was no breakdown of ages within the over 45 age group, which limits the interpretability of this finding.

Consumer Focus [38] also conducted a survey of the UK population, which identified variation in age groups at different stages of microgeneration adoption. Their results are displayed in Fig. 3 which shows the percentage of each age group considered that lies within each consideration stage of the process of adopting microgeneration. The stages included were pre-consideration, consideration, preparation and adoption. The graph indicates two clear relationships at either end of the age spectrum. Higher proportions of over 65 year olds are at the ends of the consideration scale, i.e. either they have not considered installing or they have installed. Conversely, higher proportions of the under 35 year olds are in one of the considering stages, i.e. either consideration or preparation. Both the age groups adjacent to these, the 55–64 and the 35–44, exhibit a similar relationship to their age-group neighbour, with the difference between consideration stages slightly less noticeable.

The fact that the older age groups mostly lie within the pre-consideration stage or the installed stage perhaps shows that they are either unaware or simply content with their existing system (pre-consideration), or have discovered that microgeneration is suitable for them (installed) and have experienced fewer barriers to adoption (e.g. cost or suitability to home). The younger age groups mostly lie within the central consideration stages, indicating higher awareness but that perhaps other barriers, such as cost, prevent them from installing.

To summarise, whilst there are a number of suggested correlations for the relationship between age and adoption, there is no agreement in literature. It is likely that this relationship is not straightforward and that there is a complex interplay of a range of causal factors, including house size, whether they own their residence, the level of available capital for investment, the size of house or family, or the suitability of use of microgeneration within a particular home. These aspects are discussed in the following sections.

3.2. Household size and ownership

Adoption of microgeneration is more prevalent in larger houses [15,31]. This may be due to a number of factors: available space, higher energy use or perhaps a higher household income

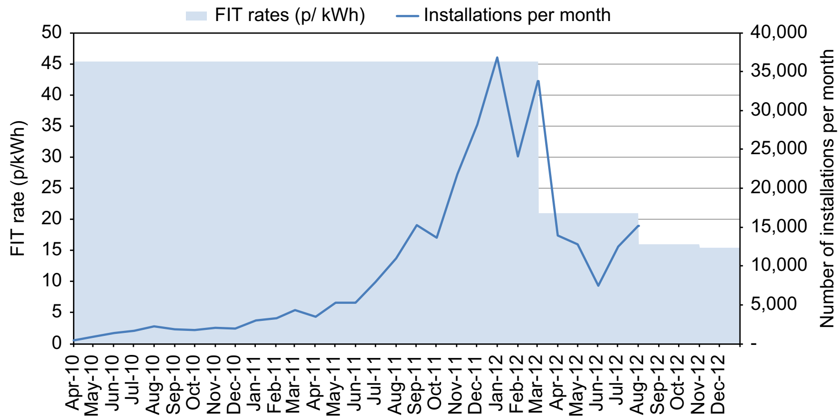

Fig. 4. Feed-in tariff (FIT) payment rates and the number of instalations per month for solar PV retrofit installations of less than 4 kW capacity [74].

(discussed further in Section 3.3). Large homes are likely to have more space to incorporate a microgeneration system. They also tend to use more energy due to larger space heating requirement, which may increase the importance of energy consumption within the home. Both of these factors potentially contribute to a greater motivation to install microgeneration. Caird and Roy [15] found that 78% of surveyed adopters lived in a larger detached house or bungalow, as opposed to 47% considerers and 44% rejecters. Most of the considerers and rejecters in the sample resided in smaller semi-detached or terraced homes. However, the study by Claudy et al. [11] tested for a relationship between household size and awareness of microgeneration and did not find any correlation.

Those who own and live in their own home are far more likely to install microgeneration [31,56]. Keirstead [31] found that of those who have installed solar PV, 97% owned their home, which is significantly higher than the 71% national average. Fischer and Sauter [56] differentiate between owners of a family home, tenants and flat owners, and suggest that only family home owners have direct control over the decision to install. Family home owners also have a direct financial motivation in benefiting from fuel bill savings, as opposed to landlords and housing associations, where these savings are normally passed on to the tenant. Further, there may be more than just a financial motivation within a family home, such as to visibly demonstrate environmental commitment or to become more secure against future fuel bill increases (as discussed in previous sections). This is less likely for a landlord as the house may be merely a financial investment rather than their residence [56]. Fischer [27] conducted a survey of 142 participants of a field test in Germany, where fuel cell CHP systems were installed in their homes. They were asked about their attitudes to energy and the environment, attitudes towards technologies, in particular fuel cell CHP, and environmental behaviour. The study compared this survey with a representative survey of the German public [69] and found that the fuel cell CHP owners had larger families and consequently larger homes, with an average of 3.15 people per household as opposed to 2.59 in an average German household.

Homes with larger families may have less disposable income or lower savings to spend on microgeneration. However, Ellison [16] finds that households with children under 16 are not significantly more or less likely to install microgeneration. Whilst available funds for an investment may be lower, the author suggests that households with younger children are less likely to move homes and so they may be more suited for a long-term investment such as microgeneration [16].

Furthermore, the length of subsidies through the FIT incentives is up to 25 years, which may be a barrier to those wishing to move house before then. Standard property rights apply to microgeneration equipment installed in the property, which means that FIT payments would be transferred to the new owners and the value of these will be set by the housing market. However, this added complication and risk of low resale value may be unwelcome by those who anticipate moving house sooner than 25 years. Particularly, there may be less willingness for older generations to become locked into a long investment that may outlive them [32].

The presence of differing opinions within a household is also a barrier for some [56]. Decisions made by a household can be very different to those made by an individual, after incorporating different preferences of the household members [34].

3.3. *Social class, income and education*

A number of studies have found correlations between awareness or adoption of microgeneration and social class [16,65,70], income and education [11,31,56]. In terms of social class, there appears to be more knowledge and awareness of microgeneration in the AB or ABC1 groups [16,65,70]. In one study, taking the example of solar PV, 28% of ABC1s stated that they knew ‘a great deal’ or ‘a fair amount’ compared to 16% of C2DEs [16]. Another study [11] suggested that the most aware of microgeneration are an upper-middle class category (social class A). Keirstead [31] also found that adopters are wealthier (40% had household incomes of greater than £50,000 pa) and have more degree-level qualifications than the national average (77% rather than 30% nationally). Similarly, Fischer and Sauter [56] identified that those most likely to adopt microgeneration (in this case fuel cell CHP) are a high-income, highly-educated ‘academic elite’.

The causality between adoption, social class, income and education is less known. Claudy et al. [11] suggest that high earners are more likely to install due to the high cost and more highly educated people are more likely to adopt due to the ‘high-involvement’ nature of microgeneration, particularly in terms of investigating prior to installation and the ‘hands on’ operation for some technologies (e.g. biomass). However, there is no justification for this correlation between education and involvement and as such it is unexplained. Conversely, Fischer and Sauter [56] suggest that income is not the reason for a greater number of installations among higher earners but instead it is due to social status and education. They also suggest that different microgeneration technologies appeal to different segments of the population: solar thermal and biomass

boilers are adopted more by farmers and skilled manual workers, whereas solar PV tends to be adopted by a high earning 'academic elite'.

On the other hand, Sopha et al. [34] find that a higher income does not imply greater likelihood of installing a microgeneration system. The results indicate that those with a higher income were more inclined to choose an electric heating system over a wood-pellet boiler or heat pump. Instead, middle income respondents were most likely to prefer a wood pellet boiler over electric heating. The authors suggest that this occurs because middle income households lie between two barriers associated with lower and higher incomes: the former group is put off by the high capital costs whereas for high-income households, fuel cost saving is not a significant issue [34].

4. Further discussion and conclusions

The literature discussed in this paper suggests that capital costs are the most important barrier for installing microgeneration technologies. This is because they are too high for the majority of potential adopters, as also indicated by the significant gap between the WTP by potential adopters and capital costs (see Table 3). However, FIT incentives have modified the UK financial landscape for those considering adoption and are likely to have increased consumers' WTP for microgeneration in the last two years, especially for solar PV. Additionally, the global solar PV market has grown significantly, leading to a drop in capital costs in the UK by around 50% between December 2010 and September 2012. At a levelised installed cost of approximately £2000/kW in September 2012 (see Fig. 2), capital costs are now approaching those found in more mature markets, for example in Germany (approximately £1500/kW) [71,72] and are far lower than in the USA (£5500/kW) [71].

The reduction in costs of solar PV is illustrated in Fig. 2, which shows UK levelised average consumer capital costs from 2006 to September 2012. These figures are for systems smaller than 4 kWp and are collated from installation quotes [22], advice from installers and the experience of adopters [19,20].[6] Within this period, UK domestic electricity prices rose by around 15%, increasing the savings made by generating electricity through PV FIT payments and resulting in higher relative financial gains from installing microgeneration. The rising electricity costs, along with high solar PV FIT rates between April 2010 and April 2012, have led to high demand for solar PV with the number of installations rising from 3000 in 2008 to 320,000 in 2012 (see Fig. 1 and Appendix A). As mentioned in the introduction, this high demand as well as significantly reduced installation costs prompted the government to halve the FIT rate in April 2012 (from 45 to 21 p/kWh). The effect of this change on demand for solar PV can be seen clearly in Fig. 4: a significant rise in demand prior to the reduction in FITs is followed by a sharp drop after it. Although the government recognised that the uptake of solar PV since April 2012 has been very low [25,73], it still subsequently announced a further reduction of FIT payments to 16 p/kWh from August 2012 [25]. This is likely to hamper further the uptake of PV and other microgeneration technologies. The demand for the latter has been low anyway (see Appendix A) as their capital costs have not decreased as drastically as PV costs.

Consumer cost reductions are most likely to occur through market development with increased uptake (such as seen with solar PV) or through policies to reduce capital costs. Policies that could further reduce capital costs include capital grants and loans, which could be paid back with money earned through FIT payments. Capital grants can be appealing to consumers as they are clearly visible (as opposed to tax relief) and easily understandable (rather than incremental incentives) [75]. Private loans specific to the solar PV market already exist in England, from a number of banks and microgeneration suppliers. The Italian government has gone a stage further, however, using low-interest loans which are directly paid back through FIT payments [76].

As opposed to barriers, the most commonly identified motivations to installing microgeneration are environmental benefit and earning or saving money through incentives and reduced fuel bills. Potential adopters are driven by the desire to show others their environmental commitment and to reduce GHG emissions but there has been little research into the WTP for this in different segments of the UK population.

Attitudes towards microgeneration and rates of installation are found to vary across age groups. However, there is no agreement on the correlation within the literature. Younger age groups (under 44) typically have a higher awareness of microgeneration and are more willing to consider installing but less frequently reach the point of installation. This suggests that other factors come in to play that prevent them from installing, such as cost. Older age groups (over 65) can be segmented into two groups: those who are unaware or simply content with their existing system and those who have installed. Those of this age group who are aware and have considered microgeneration may have experienced fewer barriers to adoption, such as cost or the suitability of their home, hence they have installed.

There are a number of factors that may directly affect barriers to installation that are likely to be correlated with age, such as whether people own a house or not, the level of available capital for investment and the size of house or family. Further investigation into these factors is required to understand why there are differing perceptions across different segments of the population.

Furthermore, in many cases, the surveys conducted were limited to the inspection of descriptive statistics. Many studies have identified some factors that affect adoption but few have investigated how important different factors are. Perhaps most importantly, there has been little research into why adoption is lower for different segments of the population and the background to the motivations and barriers that affect adoption remains unclear. Thus, to help towards a better understanding of how the uptake of microgeneration could be improved, a deeper analysis is required of the importance of motivations and barriers and possible reasons that affect people's decisions.

Acknowledgements

This work has been funded by the Sustainable Consumption Institute which is gratefully acknowledged.

Appendix A

See the Tables A1–A4.

[6] References [22] and [23] give installation costs but do not provide the source or derivation.

Table A1
Estimate of total energy contribution from microgeneration in 2008 [8].

Technology	No. of installations in 2008	Capacity (kW[a])	Energy generation (MWh/year)	Energy yield (MWh/kW.yr)
Solar PV	2993	10,354	8801	0.850
Micro-CHP	200–1000 (*mean* 600)	7000	N/A	N/A
Micro-wind	2323	4367	3825	0.876
Micro-hydro	73	921	4033	4.379
Solar thermal	97,500–102,000 (*mean* 99,750)	205,000–213,000 (*mean* 209,000)	132,000–137,000 (*mean* 134,500)	0.644
Biomass boilers	1400	28,000	23,961	0.856
GSHP	3415	22,198	58,448	2.633
ASHP	169	1146	2892	2.524
Total	**110,723**	**282,986**	**236,460**	**N/A**

[a] kWp for solar PV.

Table A2
Number of installations and capacity of microgeneration systems below 50 kW registered in the FIT database [9].

Technology	No. of installations (2012)	Capacity (kW)[a]
Solar PV	317,172	974,046
Micro-CHP	400	406
Micro-wind	2512	33,752
Micro-hydro	171	4037

[a] kWp for solar PV.

Table A3
Estimated number of total installations, capacity and energy yield of microgeneration in the UK as of the 4th quarter 2012[a].

Technology	No. of installations	Total capacity (kW)[b]	Total energy generation (MWh/yr)
Solar PV	320,165	984,400	836,750
Micro-CHP	1000	7406	N/A
Micro-wind	4835	38,119	33,388
Micro-hydro	244	4958	21,711
Solar thermal	99,750	209,000	134,500
Biomass boilers	1400	28,000	23,961
GSHP	3415	22,198	58,448
ASHP	169	1146	2892
Total	**430,978**	**1,295,227**	**1,111,649**

[a] The estimate of the microgeneration installations in the UK is assumed to be the sum of those registered with the FIT, which include those previously registered with the Renewables Obligation scheme (Table A2) and the estimate of installations by Element Energy in 2008 (Table A1). The total energy yield is estimated by scaling up the estimated energy yield per kW capacity (Table A1, column 5) to estimate total capacity, shown in Table A4.
[b] kWp for solar PV.

Table A4
Estimation of total contribution of microgeneration to UK domestic energy consumption.

	Variable	Value	Unit	Source
(1)	Energy from domestic sector	563,891,022	MWh/yr	[77]
(2)	Energy from microgeneration	1,111,649	MWh/yr	Table A3
(3)	Energy contribution from microgeneration to the final energy demand in the UK domestic sector: (3)=(2)/(1)	0.197	%	

Reference

[1] HM Government. Energy Act; 2004. 〈http://www.legislation.gov.uk/ukpga/2004/20/contents〉.
[2] HM Government. The UK renewable energy strategy. In: DECC (Ed.); 2009. Crown Copyright.
[3] NHBC Foundation. Zero carbon: what does it mean to homeowners and house-builders? IHS BRE Press; 2008. 〈www.nhbcfoundation.org/Researchpublications/Zerocarbonwhatdoesitmeantohomeowners/tabid/415/Default.aspx〉.
[4] The Carbon Trust. Building the future, today: transforming the economic and carbon performance of the buildings we work in. London; 2009. Available from: 〈http://www.carbontrust.com/resources/reports/technology/building-the-future〉.
[5] EST. Feed-in Tariff scheme. Energy saving trust London; 2011. Available from: 〈http://www.energysavingtrust.org.uk/Generate-your-own-energy/Sell-your-own-energy/Feed-in-Tariff-scheme〉.
[6] NHBC Foundation. Introduction to feed-in tariffs. Milton Keynes: IHS BRE Press; 2011.
[7] HM Government. Microgeneration strategy. In: DECC (Ed.). London: Crown Copyright; 2011.
[8] Element Energy. Numbers of microgeneration units installed in England, Scotland, Wales and Northern Ireland. In: BERR (Ed.): London; 2008. Available from: 〈http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file46003.pdf〉.
[9] DECC. Monthly central feed-in tariff register statistics. In: 5920-monthly-central-feedin-tariff-register-statistics.xls; 2012. 〈www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/fits/fits.aspx〉.
[10] Allen SR, Hammond GP, Mcmanus MC. Prospects for and barriers to domestic micro-generation: a United Kingdom perspective. Applied Energy 2008;85:528–44.
[11] Claudy MC, Michelsen C, O'driscoll A, Mullen MR. Consumer awareness in the adoption of microgeneration technologies: an empirical investigation in the Republic of Ireland. Renewable and Sustainable Energy Reviews 2010;14:2154–60.
[12] Element Energy. Potential for microgeneration. Study and analysis. In: Energy saving trust (Ed.): London; 2005. 〈www.berr.gov.uk/files/file27558.pdf〉.
[13] Scarpa R, Willis K. Willingness-to-pay for renewable energy: primary and discretionary choice of British households' for micro-generation technologies. Energy Economics 2010;32:129–36.
[14] Wee H-M, Yang W-H, Chou C-W, Padilan MV. Renewable energy supply chains, performance, application barriers, and strategies for further development. Renewable and Sustainable Energy Reviews 2012;16:5451–65.
[15] Caird S, Roy R. Adoption and use of household microgeneration heat technologies. Low Carbon Economy 2010;1:61–70.
[16] Ellison G. Renewable energy survey 2004 draft summary report of findings. London: ORC International; 2004.
[17] Element Energy. The growth potential for microgeneration in England, Scotland and Wales. element energy: Cambridge; 2008. 〈http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file46003.pdf〉.
[18] HM Government. The microgeneration strategy. DTI: London; 2006. 〈http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/sources/sustainable/microgeneration/index.html〉.
[19] Gardiner M, White H, Munzinger M, Ray W.. Low carbon building programme 2006–2011 Final report. DECC: London; 2011, Crown Copyright. 〈https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48160/2578-lcb-programme-2006-11-final-report.pdf〉.
[20] Comparemysolar Ltd. Price of solar: compare prices from local installers; 2012. 〈www.comparemysolar.co.uk/price-of-solar〉.
[21] DECC. Feed-in tariffs scheme: consultation on comprehensive review phase 1—tariffs for solar PV. DECC: London; 2011.
[22] Vaughan A. Sharp drop in number of UK homes installing solar panels; 2012 〈www.guardian.co.uk/environment/2012/sep/21/drop-uk-homes-solar-panels〉.

[23] Parsons Brinckerhoff. Solar PV cost update. DECC: London; 2012. 〈http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/feedin_tariff/fits_review/fits_review.aspx〉.
[24] Cambridge Economic Policy Associates Ltd. and Parsons Brinckerhoff. Updates to the feed-in tariffs model: documentation of changes for solar PV consultation. DECC: London; 2011 〈www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/feedin_tariff/fits_review/fits_review.aspx〉.
[25] DECC. Feed-in tariffs scheme. government response to consultation on comprehensive review phase 2a: solar PV cost control. DECC: London; 2012. 〈www.decc.gov.uk/en/content/cms/consultations/fits_rev_ph2a/fits_rev_ph2a.aspx〉.
[26] Brook Lyndhurst Ltd., Mori and Upstream. Attitudes to renewable energy in London: public and stakeholder opinion and the scope for progress. In: renewables, London renewables and DTI: London; 2003.
[27] Fischer C. Who uses innovative energy technologies, why, and when? The case of fuel cell MicroCHP. 4S and EASST Conference: Public Proofs—Science, technology and democracy, 25–28 August: Paris; 2004. 〈www.tips-project.org〉.
[28] Curry TE, Reiner DM, Figueiredo MAD, Herzog HJ. A survey of public attitudes towards energy and environment in Great Britain. Massachusetts Institute of Technology, laboratory for energy and the environment: Massachusetts, MA; 2005. 〈http://sequestration.mit.edu/pdf/LFEE_2005-001_WP.pdf〉.
[29] Faiers A, Neame C. Consumer attitudes towards domestic solar power systems. Energy Policy 2006;34:1797–806.
[30] Jager W. Stimulating the diffusion of photovoltaic systems: a behavioural perspective. Energy Policy 2006;34:1935–43.
[31] Keirstead J. Behavioural responses to photovoltaic systems in the UK domestic sector. Energy Policy 2007;35:4128–41.
[32] Mahapatra K, Gustavsson L. An adopter-centric approach to analyze the diffusion patterns of innovative residential heating systems in Sweden. Energy Policy 2008;36:577–90.
[33] Goto H, Toshio A.. Analysis of residential customers' preferences for household energy systems. IAEE European Conference, Vienna, 31 August; 2009.
[34] Sopha BM, Klöckner CA, Skjevrak G, Hertwich EG. Norwegian households' perception of wood pellet stove compared to air-to-air heat pump and electric heating. Energy Policy 2010;38:3744–54.
[35] Warren P. Uptake of micro-generation among small organisations in the Camden climate change alliance. Master's thesis, Durham University; 2010.
[36] Palm J, Tengvard M. Motives for and barriers to household adoption of small-scale production of electricity: examples from Sweden. Sustainability: Science, Practice, and Policy 2011;7:6–15.
[37] Claudy MC, Michelsen C, O'driscoll A. The diffusion of microgeneration technologies—assessing the influence of perceived product characteristics on home owners' willingness to pay. Energy Policy 2011;39:1459–69.
[38] Consumer Focus. Keeping fit consumers' attitudes and experiences of micro-generation. In: Energy saving trust and DECC (Eds.): London; 2011. 〈www.consumerfocus.org.uk/publications/keeping-fit-consumers-attitudes-and-experiences-of-microgeneration〉.
[39] Leenheer J, De Nooij M, Sheikh O. Own power: motives of having electricity without the energy company. Energy Policy 2011;39:5621–9.
[40] Element Energy. The growth potential for microgeneration in England, Wales and Scotland. BERR, London; 2008. Appendix. Page 12: Table 7.
[41] Bergman N, Hawkes A, Brett DJL, Baker P, Barton J, Blanchard R, et al. UK microgeneration. Part I: policy and behavioural aspects. Proceedings of Institution of Civil Engineers: Energy 2009;162:23–36.
[42] NHBC Foundation. A review of microgeneration and renewable energy technologies. London: IHS BRE Press; 2008. 〈www.nhbcfoundation.org/Researchpublications/Researchpublicationsfeedback/microgenerationandrenewableenergytechnologies/tabid/414/ItemId/131/Default.aspx〉.
[43] Watson J, Sauter R, Bahaj B, James P, Myers L, Wing R. Domestic micro-generation: economic, regulatory and policy issues for the UK. Energy Policy 2008;36:3095–106.
[44] Dastrup SR, Graff Zivin J, Costa DL, Kahn ME. Understanding the solar home price premium: electricity generation and Green social status. European Economic Review 2012;56(5):961–73.
[45] Hoen B, Wiser R, Cappers P, Thayer M. An analysis of the effects of residential photovoltaic energy systems on home sales prices in California. In: National Laboratory, editor. Ernest Orlando Lawrence Berkeley. Orlando: Environmental Energy Technologies Division; 2011.
[46] Morris-Marsham C.. Do solar PV and solar thermal installations affect the price and saleability of domestic properties in oxford? Degree of Master of Science Built Environment. Environmental design and engineering, UC: London; 2010. 〈http://www.oxford.gov.uk/Direct/SolarValueStudyFinalReport.pdf〉.
[47] Ecohouse Solar. Solar panels to boost property prices [Online]. WordPress & the Atahualpa WP Theme; 2009. 〈www.ecohousesolar.co.uk/http:/www.ecohousesolar.co.uk/uncategorized/solar-panels-to-boost-property-prices〉.
[48] Rowley E. Renting out roof to solar power firms could make your home harder to sell, surveyors warn [Online]. London: Telegraph Media Group Limited; 2011. 〈www.telegraph.co.uk/finance/newsbysector/energy/8856365/Renting-out-roof-to-solar-power-firms-could-make-your-home-harder-to-sell-surveyors-warn.html〉 2013.
[49] Brignall M. How solar panels can dim mortgage prospects [Online]. London: The Guardian; 2012.
[50] Debenham C. Do solar panels affect house sales? [Online] Devon: YouGen Ltd; 2010. 〈www.yougen.co.uk/blog-entry/1546/Do+solar+panels+affect+house+sales'3F〉.
[51] Walters R, Walsh PR. Examining the financial performance of micro-generation wind projects and the subsidy effect of feed-in tariffs for urban locations in the United Kingdom. Energy Policy 2011;39:5167–81.
[52] Wimberly J. Banking the green: customer incentives for EE and renewables. Ecoalign, Survey report; 2008. 〈www.ecoalign.com/news/releases/banking-green-role-customer-incentives-energy-efficiency-and-renewable-energy〉.
[53] Hack S. International experiences with the promotion of solar water heaters (SWH) at household-level. Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ) Gmbh, Mexico City; 2006.
[54] Cogar D. Customer perceptions of green technologies ecopinion, Survey report: Washington, DC; 2008. 〈www.ecoalign.com/node/46〉.
[55] Nye M, Whitmarsh L, Foxon T. Sociopsychological perspectives on the active roles of domestic actors in transition to a lower carbon electricity economy. Environment And Planning A 2010;42:697–714.
[56] Fischer C., Sauter R. Governance for industrial transformation. human dimensions of global environmental change. Berlin; 2003. 〈http://userpage.fu-berlin.de/ffu/ffu_e/Publications/bc2003_proceedings.htm〉.
[57] Rae C, Bradley F. Energy autonomy in sustainable communities—A review of key issues. Renewable and Sustainable Energy Reviews 2012;16:6497–506.
[58] Praetorius B, Martiskainen M, Sauter R, Watson J. Technological innovation systems for microgeneration in the UK And Germany—A functional analysis. Technology Analysis and Strategic Management 2010;22:745–64.
[59] Zahedi A. A review of drivers, benefits, and challenges in integrating renewable energy sources into electricity grid. Renewable and Sustainable Energy Reviews 2011;15:4775–9.
[60] Williams J. The deployment of decentralised energy systems as part of the housing growth programme in the UK. Energy Policy 2010;38:7604–13.
[61] Envirolink Northwest. Giving power to people - north west of England results and best practice. Energy saving trust: London; 2010. 〈www.envirolinknorthwest.co.uk/media/1268/microgeneration_report_2010__giving_power_to_people.pdf〉.
[62] HM Government. Energy white paper. DTI: London; 2007.
[63] Mcleod RS, Hopfe CJ, Rezgui Y. An investigation into recent proposals for a revised definition of zero carbon homes in the UK. Energy Policy 2012;46:25–35.
[64] Ben Hoen RW, Cappers Peter, Thayer Mark, Sethi Gautam. The impact of wind power projects on residential property values in the United States: a multi-site hedonic analysis. In: office of energy efficiency and renewable energy and US department of energy (Eds.), Washington, D.C.: Ernest Orlando Lawrence Berkeley National Laboratory; 2009.
[65] GfK NOP. Social research renewable energy awareness and attitudes research. DTI: London; 2006. 〈www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/planning/perception/1_20091105094703_e_@@_renewableresearchmgmtsummary.pdf〉.
[66] Willis K, Scarpa R, Gilroy R, Hamza N. Renewable energy adoption in an ageing population: heterogeneity in preferences for micro-generation technology adoption. Energy Policy 2011;39:6021–9.
[67] HM Government. UK fuel poverty strategy seventh annual progress report. DECC: London; 2009. 〈www.decc.gov.uk/assets/decc/statistics/fuelpoverty/1_20091021091505_e_@@_ukfuelpovertystrategy7annreport09.pdf〉.
[68] Devine-Wright P. Local aspects of UK renewable energy development: exploring public beliefs and policy implications. Local Environment 2005;10:57–69.
[69] Hocke-Bergler P, Stolle M. Ergebnisse Der Bevölkerungsumfragen Und Der Medienanalyse Zum Thema Endlagerung Radioaktiver Abfälle. Anlagenband Zum Itas-Bericht; 2003. 〈www.Akend.De/Projekte/Umfrage-Main.Htm〉.
[70] Devine-Wright P. Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review. The university of Manchester; 2007. 〈www.sed.manchester.ac.uk/research/beyond_mimbyism〉.
[71] Seel J, Barbose G, Wiser R. Why are residential PV prices in Germany so much lower than in the United States? a scoping analysis. Environmental energy technologies division, Lawrence Berkeley National Laboratory; 2012. 〈http://eetd.lbl.gov/ea/ems/reports/german-us-pv-price-ppt.pdf〉.
[72] BSW Solar. Statistic data on the German Solar power (photovoltaic) industry. German solar industry association; 2012. 〈www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf〉.
[73] Murray-West R. Government plans to cut solar feed-in tariff. The Telegraph 2012;24(May):2012. 〈www.telegraph.co.uk/finance/personalfinance/consumertips/household-bills/9287863/government-plans-to-cut-solar-feed-in-tariff.html〉.
[74] Ofgem. Feed-in tariff payment rate table for photovoltaic eligible installations. DECC: London; 2012.
[75] Schroeder ST, Costa A, Obé E. Support schemes and ownership structures – the policy context for fuel cell based micro-combined heat and power. Journal of Power Sources 2011;196:9051–7.
[76] Candelise C, Gross R, Leach MA. Conditions for photovoltaics deployment in the UK: the role of policy and technical developments. Proceedings of the institution of mechanical engineers. Part A: Journal of Power and Energy 2010;224:153–66.
[77] DECC. Energy consumption in the UK. London: National statistics; 2012. 〈www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx〉.